

1.7 *Environmental restoration personnel shall demonstrate a familiarity level knowledge of the basic principles and concepts of soil science.*

Supporting Knowledge and/or Skills

a. *List the different soil textures and soil structures.*

Soil texture is defined as the relative proportions of the various soil separates (particle sizes) in a soil material. The continuum of soil texture is divided into various textural groups for the purpose of describing soil horizons. Three broad and fundamental groups of soil textural classes are recognized: sands, loams, and clays. The sand group includes all soils of which the sand separates make up 70 percent or more of the material by weight. A soil is designated a clay if it contains at least 35 percent clay. Loam contains many subdivisions, and is more difficult to define. An ideal loam is a mixture of sand, silt, and clay particles which exhibits light and heavy properties in about equal proportions. Most soils of agricultural importance are loam.

Soil structure is a description of the grouping or arrangement of particles in soil and is important in determining its characteristics. Structure is strictly a field term descriptive of the gross, over-all aggregation or arrangement of the primary soil separates. Four primary types of soil structure are recognized: platy, prismlike, blocklike, and spheroidal. The mechanics of structure formation are exceedingly complicated and rather obscure. The nature and origin of the parent material are important factors as are the physical and biochemical processes of soil formation, particularly those resulting in the synthesis of clay and humus. Climate is also a prime consideration.

b. *Define humus and explain its role in chemical reactions in the soil.*

Humus is partially decomposed organic matter that is only slightly soluble in water. Humus coats sand, clay, and silt particles to form topsoils, by binding these particles and contributing to the soil's structure. Humus usually possesses a negative electrical charge and tends to attract positively charged nutrient ions: potassium (K^+), calcium (Ca^{2+}), and ammonia (NH_4^+).¹ Humus has a negative charge strong enough to counteract the leaching effect of rainwater as it passes through the topsoil layer, binding the nutrients in a location accessible to plant roots. Pesticides that form cations (positively charged ions) also bond with the humus layer in a process called adsorption, decreasing their concentration in solution (and ultimately the groundwater). In addition, humus limits the solubility of certain metal cations, attenuating the migration of these potentially harmful substances in surface and groundwater. For example, the solubility of radioactive cesium (^{137}Cs) may be limited at a nuclear disposal site due to humus.

c. *Define erosion (water and wind).*

Soil erosion is the loss of topsoil, surface litter, and other soil components, primarily due

to the actions of flowing water or wind. Loss of topsoil reduces surface fertility, which in turn reduces plant coverage and the ability of plants to hold the soil accelerating the erosion process. Wind erosion is experienced where dry, bare soil exists (as in the Great Plains Dust Bowl experienced in the U.S. Midwest during the 1930s) and usually contributes to less soil loss than does water erosion. Three types of water erosion occur. Sheet erosion occurs when uniform sheets (or layers) of soil are washed away due to a wide flow of water. Rill erosion is produced when rapidly flowing surface waters form rivulets, cutting small channels into the soil. Gully erosion results when the rivulets of rapidly flowing surface water combine with subsequent rains (usually on steep, vegetation-poor slopes), cutting wider and deeper channels (gullies). Soil erosion is usually less severe in forests and rangelands than on croplands, but soil resources in these areas recover more slowly than those on croplands¹.

d. Describe mass wasting and cite an example.

Mass wasting is the downslope movement of soil and rock debris. It is a general term for a variety of processes by which large masses of earth materials are moved by gravity. Landslides and soil creep are examples of mass wasting.

e. Describe the following processes and explain how water and soil interact in each:

- Infiltration and percolation
- Groundwater recharge
- Run-off
- Evapotranspiration
- Unsaturated flow

The flow of water through the environment is known as the hydrologic cycle. This cycle facilitates the dispersion of nutrients through the environment. The hydrologic cycle consists of evaporation, transpiration, condensation, precipitation, infiltration, percolation and runoff. Evaporation is the process of water being converted into water vapor and transpiration is the process of water being transported through a plants parts to be evaporated into the atmosphere (also known as evapotranspiration). Condensation is the formation of water droplets from water vapor. Precipitation is the deposition of condensed water vapor as dew, rain, snow, sleet, or hail. Infiltration is the movement of water into the soil. Percolation is the downward flow of water through soils and permeable rock layers into groundwater (this process is known as groundwater recharge). Runoff is the surface flow of water that does not infiltrate into the soil. Differences in energy with regard to free water as opposed to water in the soil as expressed per unit quantity of water is known as its potential. The downward flow of water through unsaturated soils is primarily due to its gravitational potential. Matric potential affects unsaturated soils and is the result of surface tension and adhesion of water to the surface of the soil. In addition, osmotic potential results from dissolved molecules and ions. Water usually moves from areas of high potential to areas of lower potential. However, water does not usually move from clay to sand-- even though the sand is drier, due to the higher adsorption properties

of clay. In drier soils, water is more strongly held at power potentials and is mainly restricted to narrow pores, resulting in the water flowing more slowly in unsaturated soils compared to the rate of flow through saturated soils.¹

f. Describe the uncertainties of the universal soil loss equation.

The soil loss equation identifies the factors on which erosion losses depend. The computed soil loss per unit area, is the product of the following factors: rainfall, soil erodibility, slope length, slope gradient, crop management (vegetative cover), and erosion-control practice.¹ Uncertainties are associated with the general lack of quantification with many of the factors of the equation and the exact mathematical relationships of their interactions.

¹ Brady, Nyle C., *The Nature and Properties of Soils*, 8th ed., Macmillian Publishing Co., NY, 1974.

1.8 *Environmental Restoration personnel shall demonstrate familiarity level knowledge of the basic principles and concepts of hydrology.*

Supporting Knowledge and/or Skills

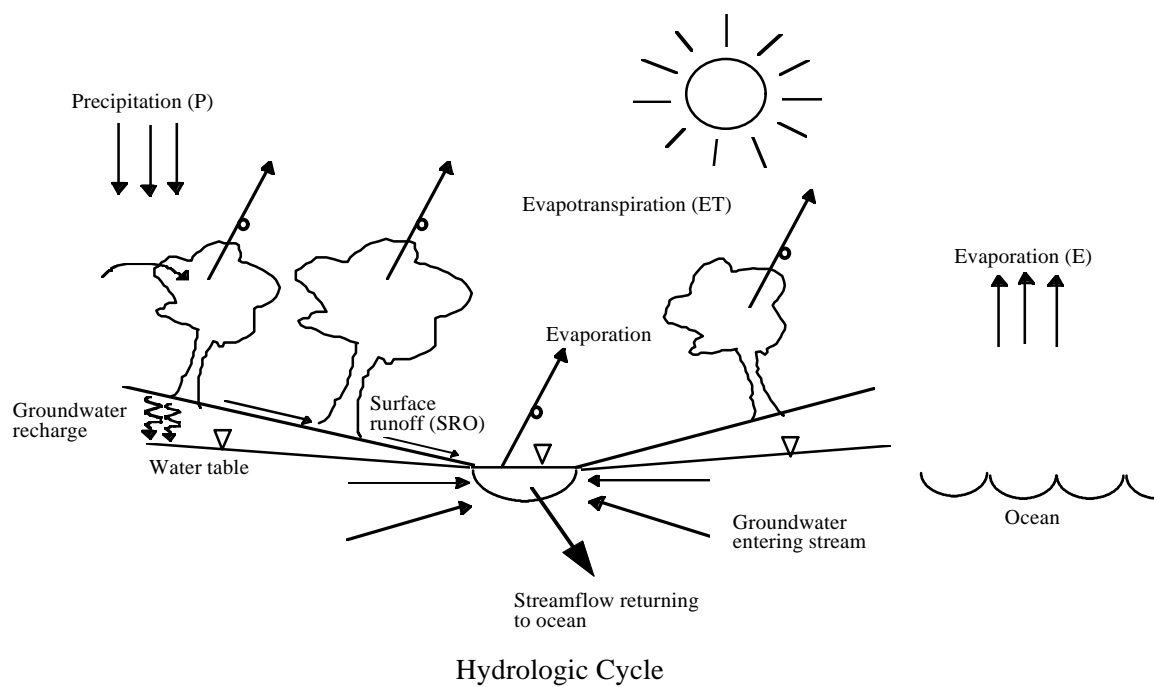
a. *Define hydrology*

Hydrology is the study of the occurrence and distribution of water, both on and under the earth's surface. Through hydrologic analysis, engineers are able to quantify the flow of water under a variety of circumstances, allowing them to safely locate and design structures in or adjacent to waterways. Hydrologic analysis is also used to study water supply, design remedial environmental cleanup, and develop environmental protection measures.¹

b. *Describe the hydrologic cycle.*

Precipitation is the starting point for the hydrologic cycle (Figure 1.8-1). As rain falls, some is intercepted by plants and buildings, and never reaches the ground. Some infiltrates into the ground, and some runs off over the ground surface. A large portion of the infiltrated water is taken up by plants and evapotranspired back into the atmosphere. The remainder enters the saturated groundwater and eventually flows back to the surface water system. Some of the runoff flows into depressions, where it either infiltrates to the groundwater, or evaporates into the atmosphere. A portion of the original precipitation runs off into the stream network. The hydrologic cycle eventually closes when water is evaporated from the oceans and lakes and delivered again through precipitation by weather systems (Figure 1.8-1).²

Figure 1.8-1¹



c. *Define the following hydrologic terms and describe the relationships between them:*

Precipitation is water droplets or ice particles that have condensed from atmospheric water vapor and are sufficiently massive to fall to the earth's surface as rain or snow. Several conditions must be met: (1) a humid air mass must be cooled to the dew point temperature; (2) condensation or freezing nuclei must be present; (3) droplets must coalesce to form raindrops; and (4) the raindrops must be of sufficient size when they leave the clouds to insure that they will not totally evaporate before they reach the ground.²

All surface and sub-surface water flows originate as precipitation. Evaporation and evapotranspiration return water vapor to the atmosphere to feed precipitation.

Stream flow is surface water which originated as runoff from precipitation or from groundwater sources and is moving down the elevation gradient. Most of this surface water either reaches the oceans, infiltrates into the groundwater, or evaporates.

This part of the hydrologic cycle is the excess water which is not used by vegetation and/or cannot be retained as groundwater due to insufficient infiltration (runoff) or flows back to the surface as recharge to streams.

Evaporation is the conversion of liquid water into vapor, especially surface water into atmospheric water vapor. Water molecules are continually being exchanged between a liquid and atmospheric water vapor. When the amount of water passing into the vapor state exceeds the amount moving into the liquid state, evaporation results. Condensation is the opposite process and occurs when the air mass can no longer hold all of the water vapor that it contains.

Evaporation is the source term for the hydrologic cycle. Most of earth's precipitation originates from evaporation of ocean surface waters. Transpiration (or evapotranspiration) is also like "evaporation" in that it is a method of returning surface water to the atmosphere, but in this case via living creatures.

Transpiration is the return of water to the atmosphere via living creatures.

In plants, transpiration is a product of photosynthesis as waste products are carried off through the stomata. Most of the vapor losses from a land-dominated drainage basin results from plant transpiration². A much less significant source is from animals where the vapor is given off through the pores of the skin. Respiration is a similar process in animals that returns a small amount of water to the atmosphere. See evaporation, above, for effects on the hydrologic cycle.

Subsurface water (groundwater) is water that is below the earth's surface, which is a part of the saturated zone below the water table, especially that between saturated surface soils and rock layers.

The main source of groundwater is direct infiltration of precipitation and infiltration from collection depressions. This subsurface reservoir of water usually moves laterally (slowly) but sometimes is trapped in stagnant basins in low precipitation / runoff regions. Groundwater supplies wells and springs, and also recharges surface runoff directly.

Sediment is the material that settles to the bottom of a liquid. Sedimentation is the deposition of terrestrial materials that were transported either by air or water.

Sedimentation is a byproduct of the hydrologic cycle where surface materials are transported to lake beds and ocean floors. Over geologic time, sediments have formed rock layers which determine the limits of groundwater movements due to their inherent permeability.

The **vadose zone** is that area which is below the earth's surface and above the groundwater layer (water table). It is considered the zone of aeration. The vadose zone is a three-phased system comprised of soil, water, and air. Water is in both the liquid and vapor phase. Smaller capillary pores may actually be saturated in the vadose zone.²

This zone is significant to hydrology and especially to the environmental sciences in that water must pass vertically through this zone before it moves laterally as groundwater. It is in this zone that migration of contaminants becomes a critical issue that determines the overall environmental impact.

The **saturated zone** is the groundwater area that lies below the aerated or vadose zone. The water table is at the top of the saturated zone. It is referred to as an aquifer. The saturated zone is the groundwater zone in which water and, therefore, contaminants are transported laterally. This movement of groundwater is what allows groundwater to play a role in the hydrologic cycle. Wells tap into the saturated zone when it lies below the surface of the ground; springs produce stream flow or recharge surface waters where the saturated zone meets the surface.

Construction that penetrates into the saturated zone raises a host of requirements and building specifications, such as waterproofing, corrosion and erosion, etc. Lateral transport of environmental contaminants, and their reintroduction into the surface waters, is a major area of concern to the environmental scientist. Dense non-aqueous phase liquid (DNAPL) contaminants will pass vertically through groundwater and pool on an impermeable surface generally along the bottom of the aquifer. Their presence can only be detected from the generally low concentrations that will dissolve in the groundwater or from their presence in the vadose zone soils.

Attenuation is the reduction in amount or concentration (dilution) of a substance of interest, usually over distance.

Attenuation is important in civil engineering both as a design feature, where attenuation is designed into a system such as a sanitary waste treatment system, and as an environmental variable, where the substance of interest (contaminant) is migrating from some source

term. The concentration of contaminants usually is reduced with distance from the source by the process of attenuation.

Dispersion is the movement in all directions of a substance of interest from the point of origin to a distant point, accompanied by a decrease in concentration. Dispersion of contaminants occurs in groundwater even if the groundwater is not itself moving. It is a process of natural mixing of the contaminant into the groundwater.

This process involves the usually unwanted movement of a substance (contaminant) by air, water, or some other natural agent. Dispersion unintentionally introduces the substance into areas which were not designed to contain or confine it, resulting in a potential exposure of the ecosystem and/or population to the substance.

Permeability is the property or capacity of a porous material such as a rock, sediment, or soil to transmit a fluid; it is a measure of the relative ease of fluid flow under unequal pressure (head).

Highly permeable soils allow precipitation to quickly infiltrate to the water table. Low permeable soils restrict infiltration, causing increased runoff and slower recharge of the groundwater supply. A perched water table can occur locally where water is contained by soils of low permeability which lie above the water table. Artesian conditions can occur if an inclined soil layer of high permeability is confined by an overlying layer of low permeability. The pressure in the artesian layer is then governed not by the local water table but by a higher elevation water table at a distant location where that layer is not confined.

Porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices, whether the interstices are isolated or interconnected. Highly porous media in which the interstices are not interconnected will not transmit fluids while media with little porosity but with interconnected interstices will transmit fluids.

Conductivity, known as hydraulic conductivity, is the rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft²). In the International System, the units are m³/day/m² or m/day. Hydraulic conductivity is governed by the size and shape of the pores, the effectiveness of the interconnection between the pores, and the physical properties of the fluid.³

d. Describe the flow of groundwater in the subsurface and discuss the importance of this to environmental restoration.

As discussed in the definitions and relationships above, excess water (usually from precipitation) that infiltrates the soil and is not used by plant life migrates downward. The water passes essentially vertically through the vadose zone and ultimately reaches the water table. It may also get trapped temporarily in a perched water table. Once water has arrived at the water table, lateral movement down the hydraulic gradient occurs as does

vertical mixing with existing groundwater in the aquifer. Groundwater may be thus transported great distances, over very long time periods. This water may be returned to the surface at varying distances from its point of infiltration by wells, springs, and direct recharge of surface waters.

If, in the process of moving from the surface to the groundwater aquifer, the water is contaminated by a hazardous substance, the moving water may become the transporting agent for the environmental contaminant. Vertical movement through the vadose zone creates one set of cleanup challenges; lateral movement in the aquifer creates a completely different set. Ultimately, the real risk to populations and ecosystems is when and if the hazardous substance is returned to the surface. Most cleanup technologies mitigate the risk of this reintroduction into the environment by removing the source of contamination and then by treating or isolating the impacted groundwater. The source of contamination may be located in the vadose zone or a non-aqueous phase liquid that is pooled on the water table or, if denser than water, within the groundwater.

¹ *Principles and Practices of Civil Engineering* 1st edition, Potter (section by D.A. Hamilton), published by Great Lakes Press, 1994.

² Fetter, C. W. Jr., *Applied Hydrogeology*, Charles E. Merrill Publishing Co. Columbus, OH., 1980.

³ Driscoll, Fletcher G., *Groundwater and Wells*, Johnson Division, St. Paul, MN, 1986.

1.9 *Environmental restoration personnel shall demonstrate a familiarity level knowledge of the basic principles and concepts of geology.*

Supporting Knowledge and Skills

a. *Discuss the following types of rocks, cite examples of each and how it relates to water, vapor, or contaminant movement:*

- **Igneous**
- **Sedimentary**
- **Metamorphic**

Minerals are the building blocks of rocks. Rock forming minerals are generally defined as naturally occurring chemically distinct materials that have a defined, repetitive internal structure. A rock is usually an aggregate of one or more types of minerals. Rocks are divided into three types: igneous, sedimentary, and metamorphic.

Igneous Rocks

Igneous rocks are formed by solidification from a molten or partially molten magma. A magma is a naturally occurring mobile rock material, generated within the earth and capable of intrusion into the upper crust of the earth or extrusion onto the surface of the earth. Magma consists of a liquid melt phase and a number of solid phases of suspended crystals of various minerals. In some cases a gas phase also may be present. Below the earth surface, intrusive igneous rocks form from the injection of magma into zones of weakness or from the heating and melting of older rocks that have become deeply buried. Intrusive igneous rocks are characterized by larger crystals that have formed from the slow cooling and resulting slow crystallization process. Examples are granite, quartz monzonite, diorite, and gabbro. Extrusive igneous rocks are formed from magma that has been released in the liquid state to the earth surface typically by volcanic eruption. Extrusive igneous rocks are characterized by relatively small crystals that are formed by rapid cooling permitted at the earth surface. Examples are andesite, basalt, and pumice. In some cases the cooling process is so rapid that no crystals form and the resulting amorphous material is called obsidian.

Composition

The chemical makeup of the magma determines the mineralogical makeup of the igneous rocks that are derived from it. As a consequence of original cooling of the earth, chemical and mineral differentiation within the crust occurred. The differentiation process was largely driven by the temperature at which various minerals crystallize and the density of those minerals. The differentiation process resulted in heavier rocks forming the deeper, oceanic crust and lighter rocks forming the relatively shallow, continental crust. As a result igneous activity associated with oceanic crust is more typically associated with the

formation of darker colored rocks that are composed of dense minerals. Typical of such rocks are those found in the lava flows of Hawaii. Basalt is typical of the igneous rocks that are associated with oceanic crust. The igneous activity associated with continental crust is more typically associated with rocks that are composed of less dense minerals. Granite is typical of the igneous rocks that form in the continental crust. Extrusive and intrusive igneous rocks form from both oceanic and continental magmas.

Identification

Igneous rocks are identified by the types of minerals present. Igneous minerals are those that formed from a molten magma. Not all minerals can be formed by the process of solidification from the molten state. The texture of the rock is an important means of identification. Igneous rocks tend to have very little visible porosity. The solidification process that results in the formation of the igneous rock causes the crystallizing minerals to grow together in a solid mass. Some types of minerals have a great propensity to form well defined mineral shapes, while other minerals fill intercrystalline spaces without developing well defined crystal faces. However, those magmas that contain a gas phase may result in the formation of highly porous igneous rocks. These rocks usually have very small crystals and a jagged appearance due to the rapidity and violent nature of their formation. Pumice is an example of a porous igneous rock.

Igneous rocks tend to be harder than other types of rocks. The minerals from which igneous rocks are formed are typically hard and this hardness is conveyed to the rock. Intrusive igneous rocks tend to form in large irregular blocks often in the uplands of mountain ranges. Therefore, the lack of appearance of tabular bedding associated with sedimentary rocks may indicate igneous rocks. However, some intrusive igneous rocks may have been injected between layers of sedimentary rocks and, subsequently, have the same layered occurrence as the rocks around them. Extrusive igneous rocks may also have a layered appearance if they were extruded on a reasonably flat surface.

Properties

Igneous rocks have a wide variety of properties because of the difference in the magma from which they formed, from the method of their formation, and from the effects of weathering after formation. Igneous rocks are usually not good aquifers because they have very little porosity. However, they can transmit water very efficiently if they are highly fractured. In such cases they may serve as a conduit through which groundwater can move from a source or recharge area to a discharge area.

Sedimentary Rocks

Sedimentary rocks are formed by the lithification of sediments usually in layers under relatively low temperature and pressure at or near the earth surface. Sedimentary rocks may also form from the precipitation of minerals such as calcite from a sea water brine.

Sediments are derived by the processes of weathering of other rocks and are transported to other areas by the action of wind, water, ice, and gravity. Sediments, once transported, are deposited as loose materials, generally in layers, that may eventually become solidified. Most sedimentary deposits are associated with the action of water. Slow-flowing or standing water will deposit sediments that have been carried by faster moving water. Where conditions are favorable for deposition, layers or strata gradually accumulate. As accumulations thicken, pressure from above compacts the underlying sediments and squeezes out much of the water contained in the sediments. Inter-granular chemical reactions and reactions with the dissolved constituents in the water results in cementation of the sediment particles into a lithified mass or sedimentary rock.

Sandstone and conglomerate are examples of sedimentary rocks that are formed from sand and gravel deposits. Shale is the sedimentary rock that forms from clay deposits. Limestone and dolomite are the typical sedimentary rocks that form from the precipitation of minerals from a sea water brine.

Composition

The composition of sedimentary rocks vary considerably. This is due to the variability in the sources of the sediments and the weathering impacts on those sources. Sediments may consist of various sizes, mineral compositions including organic compounds, and have a variety of physical properties.

Sandstone and conglomerate are two typical types of sedimentary rocks. They are characterized by particles of sand and gravel that have been lithified. The sand and gravel particles usually have a high quartz content but can contain a variety of other minerals most typically feldspar. Shale is another type of sedimentary rock. It forms from the compaction of clay particles. Clay is formed from chemical reactions resulting from the weathering of minerals found in igneous and metamorphic rocks. Limestone and dolomite are sedimentary rocks that form from chemical precipitation from sea water brines. Limestones can also contain large amounts of shells from marine animals.

Identification

Sedimentary rocks are identified by typical layered character that results from the method of sedimentary deposition. Sedimentary rocks can usually be found in relatively thin but laterally extensive strata. These strata are usually layered to form thick sequences of rock that reflect a variety of successive environments of deposition.

Unlike igneous rocks, sedimentary rocks usually result from processes that tend to weather away less chemically and physically stable minerals. As a consequence sedimentary rocks usually consist of only a limited number of very stable minerals.

Some sedimentary rocks contain fossils. The appearance of fossils is an almost absolute indication of sedimentary origin. Igneous and metamorphic processes so completely change source materials that fossils are not preserved.

Properties

Sedimentary rocks are the softest and most pliable of the rock types. Sediments are held together less firmly than the minerals in igneous and metamorphic rocks. Even though sediments such as quartz can be very hard, the rigidity of sedimentary rocks is reduced because of the cementation that holds the sediments together. Shale can be very soft because it is composed of clay.

Sandstone, conglomerate, and some limestones can be highly porous and may be very good aquifers. These rocks can also be highly fractured or in the case of limestone can contain caverns that will transmit water very rapidly. Shale is usually very impermeable and typically forms good aquitards or barriers to groundwater flow. However, hard highly lithified shale may be extensively fractured and, thereby, becomes a good transmitter of water.

Metamorphic Rocks

Metamorphic rocks are rocks that have had their original form altered by one or more geological processes (such as heat, pressure, and chemical action). Due to alteration, the rock is changed (metamorphosed) into a rock with different texture, structure, mineral composition, or general appearance. The original chemical composition of the rock, however, remains unchanged through the alteration process because there is usually no movement of materials in or out of the altered rock mass. High grade metamorphism is due to intense heat and pressures deep beneath the earth surface.

All types of rock (igneous, sedimentary, and metamorphic) can be subjected to sufficient heat and pressure to alter their structures. As a consequence, all rocks have a metamorphic equivalent. The metamorphic rock type depends on the original rock characteristics and the nature, intensity, and duration of the metamorphic activity that it has undergone.

Metamorphic rocks are the least common of the three rock types found on the earth surface. They are more often found below the surface, deep within the crust. When they are exposed, it is usually due to tectonic activity that has resulted in uplift.

Examples of metamorphic rocks are gneiss, schist, slate, and marble. Gneiss and schist typically form from the metamorphism of quartz and feldspar rich parent rocks. Slate forms from parent rocks rich in clay minerals. Marble forms from limestone and dolomite parent rocks.

Composition

The composition of metamorphic rocks is dependent on the composition of the parent rock. The chemical composition is not changed from the parent rock because no net movement of material into or out of the rock mass usually occurs. However, the mineral composition is frequently changed with the formation of minerals that are stable at higher temperatures and pressures.

Identification

Metamorphic rocks show evidence of change resulting from the processes of heat and pressure. As a result, some metamorphic rocks may be identified by distortions in shape, through separation of minerals within the rock especially into bands or swirls often of different colors, and through bending of layers within the rock (not to be confused with folds of rocks layers that are discussed below).

Properties

Metamorphic rocks, because of the variety of parent rocks and the differences in time and intensity of metamorphic processes to which the parent rocks have been subjected, exhibit a variety of properties. Intense metamorphism results in high grade metamorphic rocks that are similar to some intrusive igneous rocks such as granite. Less intense metamorphism may not change the character of the parent rock very much at all. Harder, higher grade metamorphic rocks may be highly fractured and, therefore, may be good transmitters of groundwater. Lower grade metamorphic rocks are usually not highly fractured and because of their low permeability can be poor groundwater transmitters. Marble, the metamorphic equivalent to limestone, can be a good transmitter of groundwater when caverns or fractures are present.

b. Describe the elastic properties of rocks.

Rocks respond to stress by elastic deformation, plastic deformation, and rupture. Stress is the force placed on the rock mass. Strain is the deformation that is caused by the stress. The weight of the overlying body of rock places a downward force on the rocks that is balanced by an upward force from the incompressibility of the rocks below. These forces stress the rocks proportional to the depth of burial and the density of the overlying rocks.

If a rock body is subjected to directed forces, it usually passes through the three stages of deformation listed above. At first, the deformation is elastic; that is, if the stress is withdrawn, the body returns to its original shape and size (as long as the stress does not exceed the elastic limit). If this limit is exceeded, the rock body does not return to its original shape. Below the elastic limit, the deformation obeys Hooke's law, which states that strain is proportional to stress.

If the stress exceeds that elastic limit, the deformation is plastic; that is, the rock mass only partially returns to its original shape even if the stress is removed. When the stress

increases, one or more fractures develop, and the rock mass eventually fails by rupture. Brittle rocks are those that rupture before any plastic deformation occurs. Ductile rocks are those that undergo a large interval of plastic deformation between the elastic limit and rupture.ⁱⁱ

c. *Describe the strength properties of rocks.*

Strength, sometimes referred to as rupture strength, may be defined as the force per unit area necessary to cause rupture at room temperature and atmospheric pressure in short-time experiments. Under these conditions most rocks are brittle and, consequently, little or no plastic deformation precedes the rupture.²

However, rocks at depth are subjected to conditions that are not represented on the earth surface. Other important factors to rock deformation are confining pressure, temperature, time, and solutions. Experiments have shown that rocks can withstand greater compressive stress when they are under higher confining pressure, pressure associated with depth of burial. Consequently, rocks become more ductile with depth of burial and will deform plastically under the same compressive stress that would result in rupture at the surface.² Increasing temperature also increases the range of plastic deformation before rupture occurs.

Deformation of rocks has been shown to occur if even a small stress is placed on the rocks for a long time period. Creep refers to slow deformation under stress acting over long time periods. Ordinarily, creep is restricted to deformation resulting from stresses below the elastic limit but the term is also applied to plastic deformation under any long-continued stress, even if the stress exceeds the elastic limit.³

d. *Describe the geometry and properties of the following rock masses and effects on contaminant movement:*

- Folds
- Faults
- Structural discontinuities
- Shear strength of discontinuities
- Residual stress
- Sheet joints
- Fractures

Folds

Folds are undulations or waves in the rocks. Folds are best displayed in stratified rocks such as sedimentary and volcanic rocks, or their metamorphosed equivalents. However, any layered rock, such as banded gabbro or gneiss, may display folds. Folds may be developed over very small distances of less than an inch, be several feet or even miles across. Folds can even have continental proportions of several hundred miles.

Anticlines are folds that are convex upward. Anticline, in Greek, means “opposite inclined.” It refers to the characteristic, in the simplest anticlines, of the two sides or limbs being inclined or dipping away from each other. In anticlines, the oldest rocks are exposed at the center of the fold. Anticlines generally result from compressive forces that push the earth surface together.

Synclines are folds that are concave upward. Syncline, in Greek, means “together inclined”. It refers to the characteristic, in the simplest synclines, of the two limbs dipping toward each other. In synclines, as opposed to an anticline, the youngest rocks are exposed at the center of the fold.

These simple folds can be greatly complicated by forces within the crust. Folds can be overturned such that the limbs actually dip in the same direction. They can be repeated forming a series of alternating anticlines and synclines.

In a plateau area, where strata is relatively flat, the strata may locally assume a steeper dip. Such a fold is a monocline. The beds of a monocline may dip a few degrees to 90 degrees, and the elevation of the same bed on opposite sides of the fold may differ by several hundred to thousands of feet².

Groundwater tends to flow within permeable strata that act as aquifers and tends to be confined by less permeable strata that act as aquitards. Flow is, therefore, controlled by the permeable character of the various layers of the subsurface. The difference in elevation between the recharge area and the point of discharge is the force referred to as the head that causes groundwater to flow. Therefore, flow tends to follow the topographic surface with groundwater flowing from the highest point, the recharge area, to the lowest point, the discharge area. In unfolded rocks groundwater flows along permeable beds to a point of withdrawal such as a spring, water body, or pumping well. This flow is disrupted by strata that are dipping and flow may be channeled in some other direction than that which would be expected based on the topographic surface. Flow may be directed around an anticline if the oldest rocks (the rocks at the center of the fold) are less permeable than those in the limbs. Therefore, it is the permeability differences in the different strata and the relative positions of these strata that control groundwater flow around or through folds. Each case must be analyzed individually to determine how the fold geometry and the permeabilities of the rock strata direct groundwater flow.

Faults

Stress placed on rocks results in deformation. If the deformation caused by the stress proceeds far enough, the rocks eventually fail by rupture. Failure by rupture is expressed in the rocks of the outer shell of the earth's crust by joints, faults, and some kinds of cleavage.² Rocks are characteristically broken by smooth fractures known as joints. Joints may be defined as divisional planes or surfaces that divide rocks, and along which there has been no visible differential movement of the rocks parallel to the plane of the joint. A fault occurs when differential movement in a direction parallel to the plane of the

joint has occurred. If movement at right angles to the joint surface takes place the resultant feature is called a fracture².

The attitude of fault planes that result from horizontal tensional and compressional forces is usually not vertical. Therefore, the rock on one side of the fault is essentially beneath the fault plane. The rock beneath the fault plane is called the foot wall and the rock above the fault plane is the hanging wall. Faults result from either tensional or compressional forces. Tensional forces result in a lengthening of the rock mass. Lengthening the rock mass causes distinctive relative movement along a fault plane. If a fault occurs as a result of tensional forces, the relative movement of the hanging and foot walls is for the hanging wall to move downward relative to the foot wall. Such a fault is called a normal fault. Compressive forces tend to shorten the affected rock mass. Movement along a fault resulting from compressional forces is for the hanging wall to move upward relative to the foot wall. Such a fault is called a reverse fault. Thrust faults are a special case of normal faults in which the angle of the fault plane is particularly low. The relative movement along a thrust fault plane can be extensive resulting in considerable crustal shortening.

Shearing stress may be imposed on a rock mass. Shear stress results in lateral movement along the fault plane of the rock masses relative to each other. Such faults are called strike slip faults. Strike slip faults can have a vertical plane.

Faults, fractures, and joints can have considerable impact on groundwater movement. Open fractures obviously offer an easy route for water movement. Fractures are the principal method for movement of groundwater in igneous and most metamorphic rocks because these rocks are usually not porous. However, fractures usually do not have large volume and, consequently, do not hold large volumes of water. Therefore, water will move quickly through fractures but the volume of water involved will be small unless the fractures either have wide openings or the fractured rock is porous or in contact with porous and permeable rocks. Faults may have a variety of hydraulic properties. Faults that form from compressional forces may actually seal existing permeable rocks. The compressive force in these cases causes the minerals along the fault plane to recrystallize and fill the existing pore space. Faults and fractures may have been conduits for mineralized solutions. These solutions could have deposited sufficient minerals in the fault or fracture to completely fill the void and essentially seal it to further groundwater migration.

Structural Discontinuities

Discontinuities in rocks are characterized by an abrupt change in rock type. If strata suddenly end against different rock beds, a fault may be present. Discontinuity of rock structures is characteristic of faults, but is not proof of faulting unless other possible interpretations are eliminated². Fault related discontinuities occur when movement along a fault results in dissimilar strata coming in contact with each other across the fault plane.

Structural discontinuities can impact groundwater movement. Abrupt permeability changes can occur at a structural discontinuity if the permeability of the rocks on either side of the fault plane are greatly different. An increase in groundwater mobility can occur if a saturated low permeability rock is in contact with a high permeability rock through such a discontinuity. This may result in unexpected movement of contamination.

Shear Strength of Discontinuities

Shear strength of a rock mass is the resistance of that mass to deform by slippage along an internal plane. Shear strength of a discontinuity is the mutual resistance of the two rock masses on either side of the discontinuity to slip along the plane of the discontinuity. Shear strength is a function of the discontinuity geometry and other characteristics related to its genesis. A highly undulating plane of discontinuity would have more resistance to movement than would a flat plane discontinuity. A discontinuity along a normal fault that resulted from tensional stress may be weaker than one along a reverse fault that resulted from compression stress because of the increased pressure from compression may have effectively welded the rocks across the discontinuity together.

In other types of discontinuities rock masses may have been invaded by dikes of rocks that are less resistant to weathering. In these cases the dikes, because of increased weathering, may be weaker than the invaded rocks and the shear strength of the discontinuity will be low.

The shear strength of the discontinuity will in itself not impact groundwater movement. However, if the discontinuity is characterized by hard impermeable rocks or rocks that have been highly recrystallized by the forces that resulted in the discontinuity, groundwater movement may be impeded. Also, if the discontinuity is highly weathered and the weathering results in conversion to clay minerals, the movement of groundwater may be impeded. On the other hand, if the discontinuity is characterized by highly fractured rocks that have not been welded by recrystallization, groundwater movement may be enhanced.

Residual Stress

Residual stress is the stress that remains in the rock mass after some release in stress energy has occurred. Such a release may be associated with movement along a fault during an earthquake. An earthquake occurs when the stress within the rock mass exceeds its elastic limit. Movement occurs and some part of the energy associated with the stress on the rock mass is released. In general, not all of the energy may be released and that which remains is the residual stress. In tectonically active areas, stress continues to build until another earthquake occurs.

Another example of residual stress is stress in a rock mass that remains after a glacial mass has been removed by melting. The weight of a glacier pushes the underlying rock mass downward. The elevation of the rock mass is actually depressed under the weight of the

glacier. After the glacier melts, the depressed rock mass rebounds through a process of isostatic readjustment. Isostatic readjustment lags behind the unloading of the crust caused by the melting glacier. The lag is a result of the time necessary for material deep in the crust and the upper part of the mantle to move under the area of reduced load.ⁱⁱⁱ The rocks within the crust are under a residual stress after the glacier melts but before they return to isostatic equilibrium.

Sheet Joints

Sheet joints, or sheeting, are somewhat curved joints essentially parallel to the topographic surface. The joints are close together near the surface, in many places the interval between joints may be only inches. The intervals between the joints increases with depth and a few tens of feet below the surface sheeting disappears. Sheeting is best developed in granite-like rocks but can occur in sandstone.²

The effects of sheet joints on groundwater flow is similar to that of fractures. However, sheeting effects will only be noticed in groundwater within a few tens of feet of the surface where sheet joints exist.

Fractures

Fractures are defined as joints in which the movement of the rocks on either side of a joint is perpendicular to the plane of the joint. This movement results in opening of the joint to form a void space in the rock mass. Fractures are caused by stress that result in failure by rupture of the rock mass. Fractures can form during folding, faulting, intrusion, volcanism, erosion, and weathering of the rock mass. The geometry and patterns of fractures and their distribution is related to the rock type and stress characteristics.

Control of groundwater flow by fractures has been discussed above under faults.

e. Discuss the use of geological and geotechnical maps.

Geologic and geotechnical maps illustrate stratigraphic and structural relationships between rock units exposed at the surface and are used for geological investigations (e.g., mineral and groundwater investigations) and geotechnical investigations (e.g., siting dams, power plants, buildings, slope stability studies, etc.). Geologic cross-sections drawn through select areas of the map allow the geologist to construct a three-dimensional view of the subsurface by extrapolating the rock units to show their structural and stratigraphic relationships at depth and, in some cases, in the air, as they would appear if not eroded. Geologic maps and associated cross-sections can be used to show and interpret the structural and stratigraphic influences upon groundwater systems (confined and unconfined), slip surfaces of landslides, and detailed descriptions of the geotechnical properties of the rock units.

f. Describe a geomorphic system and cite an example.

Geomorphic systems or geomorphic processes act to shape the land surface. Geomorphic systems include the action of wind; precipitation; movement of surface and groundwater; and waves as associated with climatic induced actions such as freezing on the geologic materials present to form a landscape. An example is the catastrophic floods from Lake Missoula, as recently as 15,000 years ago. The flood acted to reshape the land surface and created dramatic landforms known as the Channeled Scabland, that includes lakes; giant flood bars and ripples; terraces; coulees; and hanging valleys. Another example is the action of groundwater on limestone to form karst terrains common to many places in the United States.

g. Discuss weathering and its significance in geotechnical engineering.

Rocks undergo continuous processes that result in their weathering. Weathering processes can be mechanical (physical disintegration of the rock) and chemical (decomposition of the rock). Weathering is a key factor in the geologic processes that shape the surface of the earth. It results in the destruction of high exposed areas and creates sediment that holds moisture in low lands that are the habitats of much life. Weathering is the process of change that results from the exposure of rocks to air, water, changes in temperature, and other factors at or near the earth surface.

Mechanical weathering processes include:

- (1) Frost action, which is caused by water freezing and thawing within fractures and pores of the rock. Frost wedging is caused by water freezing and expanding in fractures prying the rock apart. Frost heaving is caused by water freezing beneath rocks and soil, lifting them;
- (2) Abrasion is caused by the grinding action due to friction and impact associated with the transportation of rocks and sediment by water or wind, and by the action of glaciers;
- (3) Pressure release results from the reduction of pressure on rocks. Pressure release is caused by the erosion of overlying rocks or the melting of glacial ice. The release of pressure causes sheet joints as previously discussed; and,
- (4) Growth of plant roots and animal burrows which also causes mechanical weathering.

Chemical weathering processes result from the reactions of chemicals in water and air with rocks. Oxygen is abundant in the atmosphere and dissolved in water. It is active chemically and often combines with elements and compounds including certain minerals found in rocks exposed to the earth surface. Leaching is a common chemical reaction that occurs in water solutions. Leaching is the process of the dissolution of minerals into water. The formation of caverns by the dissolution of limestone has been discussed and is a process of chemical weathering. Hydration is another chemical process that occurs in water. In this process water molecules combine chemically with minerals to form new compounds. This process usually results in swelling. The increased volume forces the

rock mass apart and causes concentric rock slabs to spall away from the rock mass in a process called exfoliation.

h. Discuss tests that assess weatherability.

Chemical alteration produces the effect of preconsolidation by changing the physiochemical bonds between the clay particles or by introducing stresses by the expansion or contraction of the grains during the alteration process. Most residual soils and weathered rocks exhibit this kind of preconsolidation. The preconsolidation load can be estimated from the stress-void ratio curve. Preconsolidation is extremely important in foundation engineering. A soil that is inherently compressible usually will not settle appreciably until the stress imposed by the structure exceeds the preconsolidation load.

The triaxial shear test is considered to be the most reliable strength test; the sample is subjected to confining pressure (application of axial stress or hold axial stress constant and increase confining pressure) until sample fails in shear. Weathering reduces the strength, increases the compressibility, and reduces the rigidity of intact rock.

i. Describe the process for logging rock cores.

Use a graphic log format that visually expresses the stratigraphic succession for describing continuous cores and drill cuttings. These logs should contain the following information:

- Thickness of rock units, scale of 1 inch equal 5 feet or as appropriate;
- Grain size, terrigenous clastic grain sizes and carbonate rock types using appropriate classification system (e.g., Unified Soil Classification System, Modified Wentworth Scale, Clastic Limestone Classification, Classification of Limestones According to Depositional Texture);
- Textural Maturity: detrital clay content, sorting, roundness;
- Sedimentary Structures: e.g. bedding, laminations, ripples, flow structures, etc.;
- Accessories, such as fossils, diagenetic features (cementation, mineralization, density, etc.);
- Lithologic Name and type of contact (sharp, gradational, etc.) between different lithologies;
- Moisture Content;
- Fracturing (describe pattern or type);
- Porosity estimate (with hand lens); and,
- Color using the GSA Rock Color Chart.

ⁱ Howell, J.V., *Glossary of Geology and Related Sciences* 2nd ed., American Geological Institute, Washington, DC, 1966.

ⁱⁱ Billings, Marland P., *Structural Geology* 2nd ed., Prentice Hall, Englewood Cliffs, NJ, 1965.

ⁱⁱⁱ Zumberge, James K., *Elements of Geology*, John Wiley and Son, Inc., NY, 1965.

1.11 *Environmental restoration personnel shall demonstrate a familiarity level knowledge of engineering design, and reading and interpreting of engineering and architectural drawings.*

Supporting Knowledge and/or Skills

a. *Define engineering design.*

Engineering design is the ability to combine ideas, scientific principles, resources, and often existing products into a solution of a problem. This ability to solve problems in design is the result of an organized and orderly approach to the problem known as the design process.

b. *Describe the six basic steps of the design process.*

Conceptual Design –The fundamental objectives of conceptual design are to:

- Develop a project scope that satisfies program needs, operating needs, and statutory requirements;
- Assure and/or validate project feasibility and attainable technical performance levels;
- Identify and quantify any project risks; and
- Develop a reliable cost estimate and a realistic performance schedule.

Sketches or drawings developed during conceptual design which contain necessary information related to the specific facility, such as:

- Site and location plan;
- Typical floor plan;
- Typical elevations;
- Existing utilities plan and information;
- Equipment layout plan and listing (operations or production);
- Special systems layout plan and listing; and,
- One-line piping and instrumentation diagrams (process or production flows) and other pertinent information.

Preliminary Design(Title I) – The preliminary stage of project design utilizes the conceptual design and/or design criteria that have been prepared for the project as a design basis. Sufficient design needs to be performed during Title I work to firmly fix (freeze) the project scope and features and further develop costs and schedules.

Title I Review and Approval– This review is conducted in order to: (a) evaluate the progress, technical adequacy, and risk resolution (on a technical, cost, and schedule basis) of the selected design approach; (b) determine its compatibility with performance and engineering specialty requirements of the development specification; and (c) establish the

existence and compatibility of the physical and functional interfaces among facilities, hardware, software, personnel, and procedures.

Definitive Design (Title II)– The detailed or definitive design process is performed utilizing the approved Title I design and the revised project design criteria as the design base. Completion of the definitive design ends the design phase of a project and normally allows the beginning of the construction phase. Definitive design normally includes:

- Restudy and redesign work resulting from changes as may be required from the preliminary design;
- Development of final (working) drawings and specifications for procurement and construction;
- Estimate development of construction, labor, equipment, and material quantities;
- Development of detailed estimates of the cost of construction, procurement and construction schedules, methods of performance, and identification of work packages;
- Preparation of analyses of health, safety, environmental, and other project aspects; and,
- Identification of test plan and permit requirements.

Title II Review and Approval– This review is conducted in order to: (a) determine that the detail design satisfies the performance and engineering specialty requirements of the development specifications; (b) establish the detail design compatibility among the items of equipment, facilities, computer programs, and personnel; (c) assess productivity and risk areas (on a technical, cost, and schedule basis); and (d) review the preliminary product specifications.

As-Built or Inspection (Title III)– Utilizing the Title II design package, detailed, as-built drawings are developed from inspection of the actual finished construction in the field. Shop drawings are verified, as are workmanship, materials, and equipment. Final as-built record drawings and marked-up specifications constitute the Title III design package.

- c. *Given an engineering fabrication, construction, or architectural drawing, read and interpret the basic dimensional and tolerance symbology, and basic fabrication, construction, or architectural symbology.*

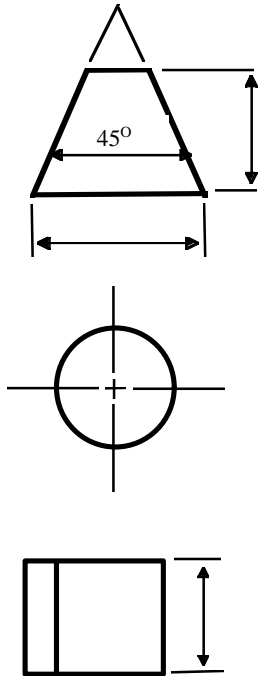
This is a demonstration requirement.

Drawings are miniature as well as picture-like representations of a building or object. Because of the relatively small size of drawings, many components cannot be shown on some drawings exactly as they look. Consequently, designers have to use a special kind of graphic language to indicate the many items that they cannot actually picture. This language employs symbols to represent materials and components. The following tables are examples of basic symbology for the listed topics. To accurately interpret the

symbolology of a drawing, check the legends and tables on the controlled drawings that are applicable to the project, since different architects and software packages may use unique symbolology.

- Basic dimensional and tolerance

Geometric characteristic symbols

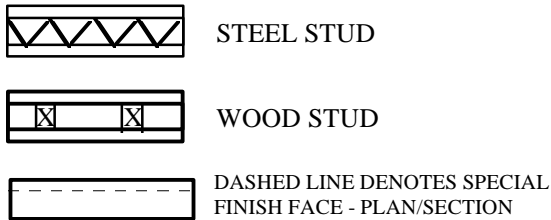


	Type of Tolerance	Characteristic	Symbol
For individual features	Form	Straightness Flatness Circularity (roundness) Cylindricity	
For individual or related features	Profile	Profile of a line Profile of a surface	
For related features	Orientation	Angularity Perpendicularity Parallelism	
	Location	Position Concentricity	
	Runout	Circular runout Total runout	

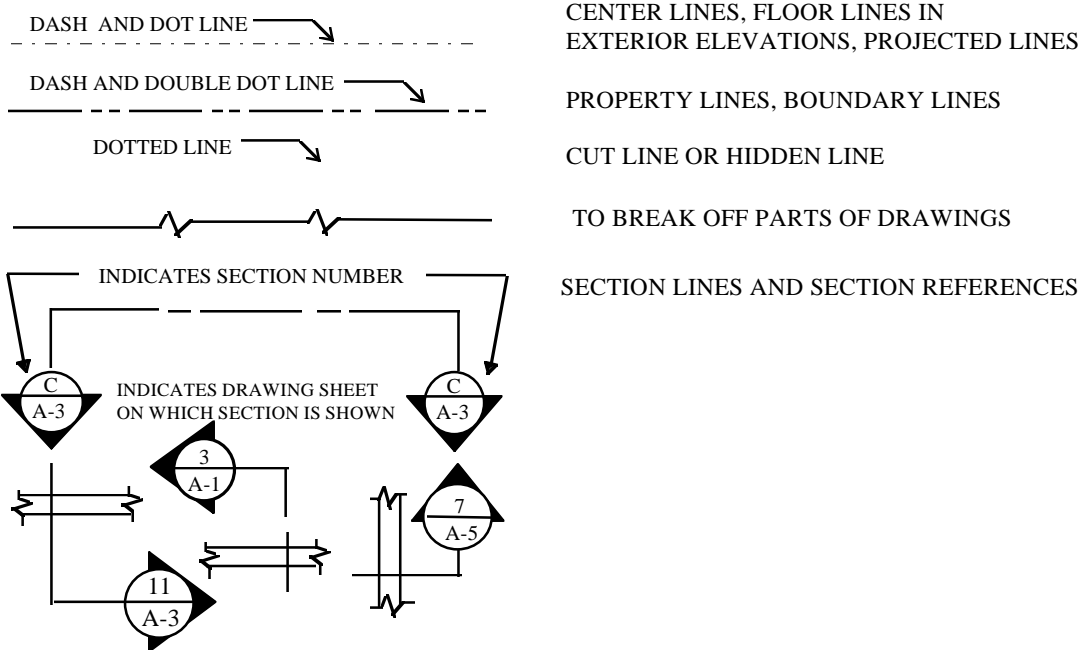
- Basic fabrication

Basic Welding Symbols and Their Location Significance								
	Fillet	Plug or Slot	Spot or Projection	Seam	Back or Backing	Surfacing	Scarf for Brazed Joint	Flange Edge
						Not used		
		Not used	Not used	Not used	Not used	Not used		Not used
	Not used	Not used			Not used	Not used	Not used	Not used

- Basic construction



- Basic architecture



¹ Wilkes, Joseph A., Robert T. Packard *Encyclopedia of Architecture, Design, Engineering & Construction* John Wiley & Sons, New York, 1989.